ATTITUDE CONTROL SUBSYSTEM (ACS) TRAINING

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All Units Are in SI (kg-m-sec) Unless Otherwise Stated
Spectrum Astro Has Responsibility for Changes to Any ACS Parameters
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ACS DESCRIPTION

Normal Mode Operation Using FSS, MAG and Torqrods
- Spin-Stabilized at 15 RPM
- Exclusive Magnetic Control
- Active Sun-Pointing (Precession) Control to < 0.2°
- Active Nutation Control
- Spin Rate Stability < 180 arcseconds in 10 revs

Initial Acquisition Using CSS, FSS, MAG and Torqrods
- Null Transverse Rates and Establishes Low Spin Rate
- Autonomous Sun Acquisition From Nominal Tip-off Orientation

Mass Balance In Idle Mode Using SAS, IAD
- On-orbit Inertia Adjustment to Align Imager with Spin Axis
## ACS PERFORMANCE REQUIREMENTS

### Parameter | Requirement | Capability | Source | Implementation | Verification Method
--- | --- | --- | --- | --- | ---
Spacecraft Attitude Stabilization | Spin stabilized | Comply | System Specification | ACS | Analysis/Operation
Spacecraft Spin Rate | 15 RPM | 15 ± 2 RPM | System Specification | ACS | Analysis
Sun Pointing Control | < 0.2 degrees | 0.14 degrees | System Specification | ACS, SMS, FSS PFS (#1110-EW-T10163) | Analysis
Spin Rate Stability | 180 arcseconds in 10 revs | 125 arcseconds in 10 revs while in Sun | System Specification | ACS | Analysis
SAS Data Compatibility | SAS as backup to FSS | SAS can not be used for ACS | System Specification | ACS | Operation
Maximum LV Tip-Off Rate | 4 deg/sec in transverse axes | 6 deg/sec | System Specification | ACS | Analysis
Initial Sun Acquisition | The S/C shall autonomously acquire the Sun from the worst Tip-Off orientation & rate upon separation from the LV | Comply | System Specification | ACS | Analysis
CSS Sun Vector Measurement Range | The CSS suite shall provide 4π steradian coverage | Comply | System Specification | ACS, SMS, CSS PFS (#1110-EW-T10164) | Analysis
## FSW Timelines and Sequence of Events

### RTS0: Initial Operations RTS

<table>
<thead>
<tr>
<th>Sep + hh:mm:ss</th>
<th>Command Function</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>25 0:00:25</td>
<td>FSW ACS Power Bus Switch ON</td>
<td>Post-Separation Sequence</td>
</tr>
<tr>
<td>26 0:00:26</td>
<td>PCB Magnetometer Power ON</td>
<td></td>
</tr>
<tr>
<td>27 0:00:27</td>
<td>PCB Fine Sun Sensor Power ON</td>
<td></td>
</tr>
<tr>
<td>28 0:00:28</td>
<td>PCB NE Heater Power Bus Switch ON</td>
<td></td>
</tr>
<tr>
<td>29 0:00:29</td>
<td>PCB SSR Heater Power Enable</td>
<td></td>
</tr>
<tr>
<td>30 0:00:30</td>
<td>PCB Battery Heater Power Enable</td>
<td>Heaters Turn-on</td>
</tr>
<tr>
<td>31 0:00:31</td>
<td>PCB Torque Rod Heaters Power Enable</td>
<td></td>
</tr>
<tr>
<td>32 0:00:32</td>
<td>PCB FSS Electronics Heater Power Enable</td>
<td></td>
</tr>
<tr>
<td>33 0:00:33</td>
<td>PCB Transponder Heater Power Enable</td>
<td></td>
</tr>
<tr>
<td>34 0:00:34</td>
<td>PCB SEM Heater Power Enable</td>
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<tr>
<td>403 0:06:43</td>
<td>PCB ACS Acquisition Mode</td>
<td>Start Sun Acquisition</td>
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<tr>
<td>4631 1:17:11</td>
<td>FSW Execute LEO Downlink RTS</td>
<td>Berkeley Pass 1 (AOS-60s)</td>
</tr>
<tr>
<td>10734 2:58:54</td>
<td>FSW Execute LEO Downlink RTS</td>
<td>Berkeley Pass 2 (AOS-60s)</td>
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<td>FSW Execute LEO Downlink RTS</td>
<td>Berkeley Pass 3 (AOS-60s)</td>
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<tr>
<td>22974 6:22:54</td>
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<td>Berkeley Pass 4 (AOS-60s)</td>
</tr>
<tr>
<td>29173 8:06:13</td>
<td>FSW Execute LEO Downlink RTS</td>
<td>Berkeley Pass 5 (AOS-60s)</td>
</tr>
<tr>
<td>79625 22:07:05</td>
<td>FSW Execute LEO Downlink RTS</td>
<td>Berkeley Pass 6 (AOS-60s)</td>
</tr>
</tbody>
</table>
## ADB RELEASE TIMELINES AND SEQUENCE OF EVENTS

### ADB Separation Sequence

<table>
<thead>
<tr>
<th>Sep +</th>
<th>hh:mm:ss</th>
<th>HCD</th>
<th>Command Function</th>
<th>State</th>
<th>Action</th>
<th>Event</th>
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<tr>
<td>0</td>
<td>0:00:00</td>
<td>N/A</td>
<td>ADB Senses LV Separation</td>
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<td></td>
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<td>30</td>
<td>0:00:30</td>
<td>HCD08</td>
<td>Primary Enable</td>
<td>Enable</td>
<td>30 second delay from sep</td>
<td></td>
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<tr>
<td>31</td>
<td>0:00:31</td>
<td>HCD04</td>
<td>± X Upper Release</td>
<td>Release</td>
<td>± X Upper Primary On</td>
<td></td>
</tr>
<tr>
<td>76</td>
<td>0:01:16</td>
<td>HCD04</td>
<td>± X Upper Release</td>
<td>Standby</td>
<td>± X Upper Primary Off</td>
<td>± X Nominal Break Upper Bolt</td>
</tr>
<tr>
<td>77</td>
<td>0:01:17</td>
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<td>Primary Enable</td>
<td>Disable</td>
<td>Disable Primary Power</td>
<td></td>
</tr>
<tr>
<td>78</td>
<td>0:01:18</td>
<td>HCD09</td>
<td>Redundant Enable</td>
<td>Enable</td>
<td>Enable Redundant Power</td>
<td></td>
</tr>
<tr>
<td>79</td>
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<td>Release</td>
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<tr>
<td>124</td>
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<td>Standby</td>
<td>± X Upper Redundant Off</td>
<td>± X Contingency Break Upper Bolt</td>
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<tr>
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<td>Enable</td>
<td>Enable Primary Power</td>
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<tr>
<td>127</td>
<td>0:02:07</td>
<td>HCD05</td>
<td>± Y Upper Release</td>
<td>Release</td>
<td>± Y Upper Primary On</td>
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<td>172</td>
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<td>Standby</td>
<td>± Y Upper Primary Off</td>
<td>± Y Nominal Break Upper Bolt</td>
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<tr>
<td>173</td>
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<td>Disable</td>
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<td></td>
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<tr>
<td>174</td>
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<td>175</td>
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<tr>
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<td>± Y Contingency Break Upper Bolt</td>
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<tr>
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<td>Primary Enable</td>
<td>Enable</td>
<td>Enable Primary Power</td>
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</tr>
<tr>
<td>223</td>
<td>0:03:43</td>
<td>HCD06</td>
<td>± X Lower Release</td>
<td>Release</td>
<td>± X Lower Primary On</td>
<td></td>
</tr>
<tr>
<td>268</td>
<td>0:04:28</td>
<td>HCD06</td>
<td>± X Lower Release</td>
<td>Standby</td>
<td>± X Lower Primary Off</td>
<td>± X Wing Nominal Release</td>
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<tr>
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<td>Enable Redundant Power</td>
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<td>271</td>
<td>0:04:31</td>
<td>HCD06</td>
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<td>Release</td>
<td>± X Lower Redundant On</td>
<td></td>
</tr>
<tr>
<td>316</td>
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<td>Standby</td>
<td>± X Lower Redundant Off</td>
<td>± X Wing Contingency Release</td>
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<tr>
<td>317</td>
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<td>Redundant Enable</td>
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<td>Disable Redundant Power</td>
<td></td>
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<tr>
<td>318</td>
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<td>HCD08</td>
<td>Primary Enable</td>
<td>Enable</td>
<td>Enable Primary Power</td>
<td></td>
</tr>
<tr>
<td>319</td>
<td>0:05:19</td>
<td>HCD07</td>
<td>± Y Lower Release</td>
<td>Release</td>
<td>± Y Lower Primary On</td>
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</tr>
<tr>
<td>364</td>
<td>0:06:04</td>
<td>HCD07</td>
<td>± Y Lower Release</td>
<td>Standby</td>
<td>± Y Lower Primary Off</td>
<td>± Y Wing Nominal Release</td>
</tr>
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<td>365</td>
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<td>HCD08</td>
<td>Primary Enable</td>
<td>Disable</td>
<td>Disable Primary Power</td>
<td></td>
</tr>
<tr>
<td>366</td>
<td>0:06:06</td>
<td>HCD09</td>
<td>Redundant Enable</td>
<td>Enable</td>
<td>Enable Redundant Power</td>
<td></td>
</tr>
<tr>
<td>367</td>
<td>0:06:07</td>
<td>HCD07</td>
<td>± Y Lower Release</td>
<td>Release</td>
<td>± Y Lower Redundant On</td>
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</tr>
<tr>
<td>412</td>
<td>0:06:52</td>
<td>HCD07</td>
<td>± Y Lower Release</td>
<td>Standby</td>
<td>± Y Lower Redundant Off</td>
<td>± Y Wing Contingency Release</td>
</tr>
<tr>
<td>413</td>
<td>0:06:53</td>
<td>HCD09</td>
<td>Redundant Enable</td>
<td>Disable</td>
<td>Disable Redundant Power</td>
<td></td>
</tr>
</tbody>
</table>
ON-ORBIT CONFIGURATION

Control System Objective

Initialization:
Bring the spacecraft axes from the worst initial tip-off attitude and body rate to Sun pointing orientation

Normal Operations:
Hold body z-axis in alignment with the reference z-axis, in the presence of sun motion and environmental disturbances

Reference Coordinate System

Z<sub>R</sub> points to the sun
Y<sub>R</sub> is perpendicular to ecliptic plane
X<sub>R</sub> completes a right-handed triad

Ecliptic Plane

Orbit Plane
(i=38°, Ω=329°, h=600 km)

Equatorial Plane

Spacecraft Body Coordinate System
Coarse Sun Sensors
(2 per wing at ±35° from wing plane)

Four wings are tilted 5 deg below horizontal

Fine Sun Sensor Head

Magnetometer

X Torqrod

Y Torqrod

Z Torqrod

ACS PHASING AND ORIENTATION
ACS FLIGHT SOFTWARE ARCHITECTURE
ACS MODES AND MODE DEFINITION

Acquisition (Wake Up) Mode
Establishes Desired Spin Rate and Damps Transverse Rates

Precession Mode
Establishes Sun-pointing Orientation

Normal Mode
Maintains Sun-pointing Orientation and Nominal Spin Rate; Encompasses Fine Precession, Nutation, and Spin Rate Control

Spin Mode
Establishes Desired Spin Rate

Idle Mode
Disables Control Until Ground Intervention

Balance Operations
Balances Spacecraft Using IADs to Obtain Pure Spin About Imager Axis

G - Ground Command
A - Autonomous Transition
U - Unresolved Error (Autonomous)

#) - Denotes Nominal Path From Acquisition to Operation
## ACS MODES TRANSITION LOGIC

<table>
<thead>
<tr>
<th></th>
<th>Acquisition</th>
<th>Precession</th>
<th>Normal</th>
<th>Spin</th>
<th>Idle</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Acquisition</strong></td>
<td>Time since LV release &gt; 2.5 hours</td>
<td>β &lt; 5.0 deg AND Ω &gt; 0.12 rpm</td>
<td>None</td>
<td>Ground Command</td>
<td></td>
</tr>
<tr>
<td><strong>Precession</strong></td>
<td>None</td>
<td>β &lt; 0.2 deg AND 14.5&lt;Ω&lt;15.5rpm</td>
<td>None</td>
<td>Ground Command OR ( \beta &lt; 5 \text{ deg} ) AND NOT ( 14.5&lt;\Omega&lt;15.5 \text{ rpm} )</td>
<td></td>
</tr>
<tr>
<td><strong>Normal</strong></td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>Ground Command OR ( \beta &gt; 0.5 \text{ deg} ) OR NOT ( 13.5&lt;\Omega&lt;16.5 \text{ rpm} )</td>
<td></td>
</tr>
<tr>
<td><strong>Spin</strong></td>
<td>None</td>
<td>None</td>
<td>14.5&lt;Ω&lt;15.5rpm AND β &lt; 0.2 deg</td>
<td>Ground Command OR ( 14.5&lt;\Omega&lt;15.5 \text{ rpm} ) AND NOT ( \beta &lt; 0.2 \text{ deg} )</td>
<td></td>
</tr>
<tr>
<td><strong>Idle</strong></td>
<td>Ground Cmd</td>
<td>Ground Cmd</td>
<td>Ground Cmd</td>
<td>Ground Cmd</td>
<td></td>
</tr>
</tbody>
</table>

**Note 1:** Autonomous Mode Transitions can Only Occur When the Sun Is in Presence  
**Note 2:** Persistence Checks are Performed for All Autonomous Mode Transitions  
**Note 3:** \( \beta = \text{Angle Between Spin Axis and Sun} \)  
\( \Omega = \text{Measured Spin Rate} \)
## ACS HARDWARE UTILIZATION

### Notes:
1. All sensors sampled at 8 Hz PACI rate
2. When FSS Sun Presence Indicator is high, FSS output supersedes CSS output
3. MAG Processing Includes Compensation for Torqrod-Generated Magnetic Field
   - Initial Compensation Matrix Generated from Ground Test
   - Matrix Obtained by Energizing One Torqrod at a Time and Measuring Field Change
4. For Normal Mode Spin Rate Control is Limited to 10 A-m^2
5. SAS is Utilized as Primary Balancing Sensor
6. SAS can Not Be Used for ACS control

<table>
<thead>
<tr>
<th></th>
<th>Acquisition</th>
<th>Precession</th>
<th>Spin</th>
<th>Normal</th>
<th>Idle</th>
<th>Balance</th>
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</thead>
<tbody>
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<td>Spin-Axis TQR</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>Y (pointing)</td>
<td>On Request</td>
</tr>
<tr>
<td>Transverse TQR</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>Y (spin rate)</td>
<td>On Request</td>
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<tr>
<td>CSS</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>On Request</td>
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<tr>
<td>FSS</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>On Request</td>
</tr>
<tr>
<td>MAG</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>On Request</td>
<td>N</td>
</tr>
<tr>
<td>IAD</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>SAS</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>On Request</td>
<td>Y</td>
</tr>
</tbody>
</table>
EVENT SEQUENCE TO NORMAL OPERATIONS

Separate from LV

Deploy arrays

Damp nutation and establish precession spin rate

Acquisition Mode
ACS Starts

[4,4,17]

Acquisition Mode
ACS Waits for 10 min

[3,3,3]

Acquisition Mode

MAG, TQR

[0,0,2]

Precession Mode

Precess spin axis towards Sun

MAG, CSS, TQR

[0,0,2]

Precession Mode

Align spin axis with Sun

MAG, FSS, TQR

[0,0,2]

Precession Mode

Precession Mode

Spin up to 15 RPM

MAG, FSS, TQR

[0,0,90]

Precession Mode

Idle Mode

MAG, FSS, TQR

[0,0,2]

Idle Mode

Adjust solar array angles to balance S/C

SAS, FSS, IAD

[0,0,90]

Idle Mode

Begin normal operations

MAG, FSS, TQR

Normal Mode

[0,0,90]

Normal Mode

=x,x,x = S/C rate vector (deg/sec)

= Autonomous

= Ground-commanded
Nominal LV Tip-off Conditions:
- Momentum Vector within 10 deg of Sun
- 4 deg/sec Transverse Rate
- 17 deg/sec Spin Rate

30-second Array Deployment with 2-second Delay between Arrays Adds 2° of Additional Nutation
Initial 2.5 hour Acquisition Mode Establishes Spin Rate and Damps Transverse Rates (B-dot)
FSS Utilized When Sun Cone Angle is within 32 Degrees
30-minute Eclipse Once per Orbit with Precession Control Disabled
WORST ATTITUDE SUN ACQUISITION

Worst LV Tip-off Conditions:
- Momentum Vector within 180 deg of Sun
- 4 deg/sec Transverse Rate
- 17 deg/sec Spin Rate

30-second Array Deployment with 2-second Delay between Arrays Adds 2° of Additional Nutation
Initial 2.5 hour Acquisition Mode Establishes Spin Rate and Damps Transverse Rates
FSS Utilized When Sun Cone Angle is within 32 Degrees
30-minute Eclipse Once per Orbit with Precession Control Disabled
SPIN RATE ESTIMATION

- \( b \) is the Projection of \( B \) onto the Spin Plane
- \( b \) is Periodic in the Body \( x \) and \( y \) Axes at Spin Period
- Absolute Spin Rate can be Determined by
  - Record \( b \) Crossing Time Period \( \Delta t \) at \( X \) Axis
  - Record \( b \) Crossing Time Period \( \Delta t \) at \( Y \) Axis
  - Spin Rate Estimate at One Axis = \( 2 \pi / \Delta t \)
  - Average \( X \) and \( Y \) Spin Rate Estimates
- Spin Rate Estimate is Updated Whenever a New Crossing Occurs
- Spin Rate Estimation Errors:
  - Bigger Errors Tend to Occur at Low Spin Rates
  - Error Varies with Orbit/Magnetic Field Positions
  - Errors due to Nutation Motion
SOLAR ARRAY FREQUENCY ANALYSIS RESULTS

**Dynamics Model Assumptions:**
- One Rigid Central Body with Zero Cross Product MOI
- 4 Rigid Panels Symmetrically Located
- Spring-damper Joints
  - 1% Damping Ratio
- 4 Solar Panels at Nominal 5° Angle

**Analysis Results:**
- HESSI 1st Mode Frequency 0.79 Hz per Structural Analysis
- For Nominal 15 rpm Spin:
  - Unstable for <= 0.43Hz 1st Mode Frequency
  - Min Nutation Frequency Occurs at 0.43Hz
- HESSI Stiffness > 3 times of Unstable Stiffness
- For 10 rpm
  - Unstable for <= 0.29Hz S/A 1st Mode Frequencies
- For 5 rpm
  - Unstable for <= 0.14Hz S/A 1st Mode Frequencies

---

**Graph:**
- **Nutation Freq vs. S/A 1st Mode Freq**
- **HESSI** Nominal

---

**Figure:**
- Diagram of Solar Array with labeled axes (X, Y, Z).
- Markers indicating different rpm conditions (15 rpm, 10 rpm, 5 rpm).
ON-ORBIT BALANCE - CONCEPT

Independent Error Sources

Body-Fixed Sensor Plane

FSS axis offset from spin axis

Imager axis offset from spin axis

Spin axis offset from Sun

F = Output in FSS Sensor Plane
I = Output in Imager Sensor Plane

Spacecraft Balance & Precession

Balance about Imager

Precess to Sun
ON-ORBIT BALANCE - CAPABILITY

Objective
- Provide On-orbit Adjustment to Compensate for Offset Between Principal Spin Axis and SAS Boresight Axis

Key Issues
- Adjustment Sensitivity
  - 0.00043 cm Linear Adjustment Resolution Equates to 0.0022° Spin Axis Angle Resolution
  - A 1° Spin Axis Capture Range Equates to
    - 455 Steps
    - 0.55 deg Array Deflection
    - Linear Adjustment of 0.2 cm
    - Net Tip Deflection of 2.2 cm
- Full Travel Range is 2.54 cm Equating to 12 Degrees of Spin Axis Range
- Estimates Show That Approximately 5% of the Rigid Body Deflection is Lost to Centrifugal Force

Tip Displacement
\[ d2 = -\frac{L_2}{L_1} \cdot d1 \]
ACS HARDWARE

ACS Interface Block Diagram
Hardware Performance and Technical Data
FOVs of FSS and CSS
Torque Rod Compensation Matrix
ACS INTERFACE BLOCK DIAGRAM

High Energy Solar Spectroscopic Imager (HESSI)

Power Control Board

- +/-15 VDC
- Gray Coded Angle Photocell Outputs (6 coarse bits and 4 fine bits per axis)
- 28 +/-6 VDC
- Drive Currents

Fine Sun Sensor Electronics

- Magnetic Field Data (analog)
- Temperature Monitor (analog)
- Fine Sun Sensor Head
- Auto Threshold Adjust (one per axis)
- Sin & Cos Fine Angle (analog)
- Sun Presence (Bi-level)
- Coarse Angle (Serial)
- Voltage Monitor (analog)

Electromagnetic Torqrods

Inertia Adjustment Devices

VME Backplane

PACI Board

- Current (analog)

IDPU

SAS

CPU
FINE SUN SENSOR HEAD

Supplier: Adcole
Supplier Part Number: Model 41660
Quantity: 1
Mass: 0.29 kg
Size: 9.6 x 9.7 x 3.6 cm
Power: n/a

Performance:
- Operational Field of View: ± 32° cone
- Sun Presence Field of View: ± 31.5° ± 0.5°
- Measurement Resolution: 0.005° for 8-bit D/A Converter, Dictated by since/cosine Signals
- Measurement Accuracy:
  - 0.05° (3σ) in ± 10° Half Cone
  - 0.1° (3σ) Outside Half Cone

Detector layout:
- 6 Gray-Coded Coarse Bits
- 4 Fine Bits
Supplier: Adcole
Supplier Part Number: Model 44000
Quantity: 1
Mass: 0.64 kg
Size: 14.0 x 9.2 x 6.4 cm
Power: 2.8 W
Output Signals:
- 10-Bit Serial Coarse Angle Data Per Axis
  - Bit 1 - Axis Identification Bit
  - Bits 2 - 4 - Zero Bits
  - Bits 5 - 10 - 6-Bit Gray Coded Coarse Angle
- 4 Fine Bits Analog Fine Angle Data (sine & cosine)
- Axes Separated by 10 msec
- Bi-Level Sun Presence Indicator
- Analog State-of-Health Signal
Sensor Data Processing

**Inputs:**
α and β Specified by an Input Pattern. Model Converts This Pattern to Interface Type Signals (Gray Coded Coarse Angle Data Plus sin and cos Fine Angle Data)

**Outputs:**
Processing Software Recovers the Original α and β Angles
COARSE SUN SENSOR

Supplier:  Adcole  
Supplier Part Number: Model 29450  
Quantity:  8  
Mass:  0.011 kg  
Size:  2.8 dia x 1.2 cm  
Power:  n/a  
Measurand:  Cosine of Angle Between Cell Normal and Sun  
Performance:  
  • Operational Field of View: ± 80° Cone  
  • Sun Presence Field of View: ± 90° Cone  
  • Peak Cell Current Output: 1.317 milli-Amps  
Interface:  Analog Output with a Two-Wire (+,-) Interface to PACI
CSS COVERAGE

HESSI CSS Configuration:
• Nominal Solar Wing Positions are 5 deg Tilting Down
• Two Cells Per Wing with Cell Normal Pointing ±35 deg Relative to Wing Panel

Shown for Nominal Solar Wing Positions:
• Coverage for Each CSS Limited to ±70° Cone Angle (34% of Full Sun) to Minimize Earth Albedo Effect
• Albedo Ranges from 27% (Summer) to 37% (Winter) at Peak Latitudes with an Orbit Average of 25%

Note:
• Four Small Regions with One Cell Coverage Caused by Solar Panel 5 deg Tilt Below Horizontal Plane

Numbers represent sensor coverage in each region
THREE-AXIS MAGNETOMETER

Supplier: Ithaco
Supplier Part Number: IM-103
Quantity: 1
Mass: 0.231 kg
Size: 15.5 x 4.2 x 3.8 cm
Power: 0.95 W
Magnetic Field Range: ± 600 mG in Three Axes
Measurement Accuracy: 4 mG (3σ)
Scale Factor: 8.3333 V/G
Bandwidth: >100 Hz
Outputs:
- Three Voltages Proportional to B field
- One Voltage Proportional to Temperature
TORQUE RODS

Supplier: Ithaco
Supplier Part Number: TR60CFR
Quantity: 3
Mass: 1.7 kg
Size: 2.8 dia x 63.8 cm
Power (Standby): 0 W
Power (Orbit Average): 0.2 W
Power (Operating): 1.3 W
Linear moment output: 60 Amp-m²
Scale factor: 0.25 Amp-m²/milli-Amp
Coil resistance: 40 Ohms
Coil inductance: 2.5 Henries
Time constant: 62.5 msec
For a Single 60 Am^2 torqrod, fully energized, the Field Strength is Shown.
• Residual fields are ~1% of the last energized field

For HESSI Configuration
When Three Torque Rods are Energized to 60 A-m^2, the Magnetic Field Strength at MAG Location is Calculated as

\[
B = \begin{bmatrix}
41.6 \\
21.2 \\
-18.3
\end{bmatrix} \text{ milliGauss}
\]

Torque Rod Compensation Matrix Limits
This Torque Rod Magnetic Field Effect On the MAG Output.
Torque Rod Compensation Matrix is Obtained by Applying A Series of Current to Each Torque Rod and Measuring Magnetometer Outputs.

More Than Four Tests Performed so far Result in the Same Compensation Matrix Used in ACS FSW:

\[
\begin{bmatrix}
V_x \\
V_y \\
V_z
\end{bmatrix} = \begin{bmatrix}
0.6713 & -0.0614 & 0.8819 \\
0.1619 & 1.0262 & -0.3627 \\
0.4246 & -0.4165 & -0.6973
\end{bmatrix}\begin{bmatrix}
I_x \\
I_y \\
I_z
\end{bmatrix}
\]
ACS SOFTWARE

ACS Operation Modes
ACS FSW Diagrams
ACS Mode Selection
ACS FSW Input/Output Modules and Variables
Input Processing
Mode Control Logic and Hot Bench Performance Results
ACS Commands and Parameters
## ACS OPERATING MODES

<table>
<thead>
<tr>
<th>Operating Mode</th>
<th>Purpose</th>
<th>Sensor Used</th>
<th>Actuator Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Acquisition</td>
<td>Damps Transverse Rates and Establishes a Desired Low Spin Rate</td>
<td>MAG</td>
<td>All Three TQRs</td>
</tr>
<tr>
<td>2. Precession</td>
<td>Points Spin Axis to Sun and Reduces Nutation</td>
<td>CSS, FSS,</td>
<td>ZTQR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MAG</td>
<td></td>
</tr>
<tr>
<td>3. Normal</td>
<td>Maintains Sun-Pointing Orientation and Nominal Spin Rate; Encompasses</td>
<td>FSS, MAG</td>
<td>All Three TQRs</td>
</tr>
<tr>
<td></td>
<td>Fine Precession, Nutation, and Spin Rate Control</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Spin</td>
<td>Establishes Desired Spin Rate</td>
<td>FSS, MAG</td>
<td>All Three TQRs</td>
</tr>
<tr>
<td>5. Idle</td>
<td>Disables Control Until Ground Intervention</td>
<td>FSS, MAG</td>
<td>All Three TQRs</td>
</tr>
<tr>
<td>Balance</td>
<td>Balances Spacecraft Using IADs to Obtain Pure Spin About Imager Axis</td>
<td>FSS, SAS</td>
<td>IAD</td>
</tr>
</tbody>
</table>
ACS FSW TOP LEVEL DIAGRAM

Ground command to select Fine Sun Sensor

(Caution)

Select

\( S_{\text{FSS}} \) or \( S_{\text{SAS}} \)

Ground Mode

Mode Selection

Mode Control Logic

Input Processing

\( B_\ell \cdot S_{\text{CSS}, \hat{\Omega}} \)

CSS SPI

Commanded current

\[
\begin{bmatrix}
I_x \\
I_y \\
I_z
\end{bmatrix}
\]

Torque Rods

(Previous)

\[
\begin{bmatrix}
I_x \\
I_y \\
I_z
\end{bmatrix}
\]
High Energy Solar Spectroscopic Imager (HESSI)

**MODE SELECTION**

G - Ground Command
A - Autonomous Transition
U - Unresolved Error (Autonomous)
# - Denotes Nominal Path From Acquisition to Operation

1. **Acquisition Mode**
   - \( \beta > 0.5 \text{ deg OR NOT } 13.5<\omega <16.5 \text{ rpm (for 2 sec)} \)
   - \( \beta \text{< 0.2 deg } \text{ AND } \omega \text{< 5.5 rpm (for 2 sec)} \)

2. **Precession Mode**
   - \( \beta < 5 \text{ deg } \text{ AND } 14.5<\omega <15.5 \text{ rpm (for 60 sec)} \)
   - \( \beta < 0.2 \text{ deg } \text{ AND } \omega < 15.5 \text{ rpm (for 600 sec)} \)

3. **Normal Mode**
   - \( \beta < 0.2 \text{ deg } \text{ AND } \omega > 0.12 \text{ rpm (for 600 sec)} \)
   - \( \beta < 5.0 \text{ deg } \text{ AND } \omega > 0.12 \text{ rpm (for 600 sec)} \)

4. **Spin Mode**
   - \( \beta > 0.5 \text{ deg OR NOT } 13.5<\omega <16.5 \text{ rpm (for 2 sec)} \)
   - \( 14.5<\omega <15.5 \text{ rpm } \text{ AND } \beta < 0.2 \text{ deg (for 2 sec)} \)

5. **Idle Mode**
   - \( \beta < 5 \text{ deg AND NOT } 14.5<\omega <15.5 \text{ rpm (for 60 sec)} \)
   - \( \beta < 0.2 \text{ deg AND NOT } \omega < 15.5 \text{ rpm (for 600 sec)} \)

6. **Balance Operations**

Ground Mode Overrides Autonomously Selected Mode
- ACSSETMODE AUTO - Allows Autonomous Mode Selection
- ACSSETMODE NORMAL - Ground Forces to Normal Mode

- Autonomous Mode Transitions Can Only Occur When the Sun is in View
- Persistence Checks Are Performed for All Autonomous Mode Transitions

\( \beta = \text{Angle Between Spin Axis and Sun} \)
\( \omega = \text{Measured Spin Rate} \)
## ACS FSW Input Variables From CDHS
- **38 Parameters**

<table>
<thead>
<tr>
<th>#</th>
<th>Variable</th>
<th>Type</th>
<th>Description</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>MAG1</td>
<td>Float</td>
<td>MAG x output</td>
<td>± 5 volts</td>
</tr>
<tr>
<td>2</td>
<td>MAG2</td>
<td>Float</td>
<td>MAG y output</td>
<td>± 5 volts</td>
</tr>
<tr>
<td>3</td>
<td>MAG3</td>
<td>Float</td>
<td>MAG z output</td>
<td>± 5 volts</td>
</tr>
<tr>
<td>4</td>
<td>CSS1</td>
<td>Float</td>
<td>CSS 1 (CX11) output</td>
<td>0 − 0.0013 amps</td>
</tr>
<tr>
<td>5</td>
<td>CSS2</td>
<td>Float</td>
<td>CSS 2 (CX10) output</td>
<td>0 − 0.0013 amps</td>
</tr>
<tr>
<td>6</td>
<td>CSS3</td>
<td>Float</td>
<td>CSS 3 (CX01) output</td>
<td>0 − 0.0013 amps</td>
</tr>
<tr>
<td>7</td>
<td>CSS4</td>
<td>Float</td>
<td>CSS 4 (CX00) output</td>
<td>0 − 0.0013 amps</td>
</tr>
<tr>
<td>8</td>
<td>CSS5</td>
<td>Float</td>
<td>CSS 5 (CY11) output</td>
<td>0 − 0.0013 amps</td>
</tr>
<tr>
<td>9</td>
<td>CSS6</td>
<td>Float</td>
<td>CSS 6 (CY10) output</td>
<td>0 − 0.0013 amps</td>
</tr>
<tr>
<td>10</td>
<td>CSS7</td>
<td>Float</td>
<td>CSS 7 (CY01) output</td>
<td>0 − 0.0013 amps</td>
</tr>
<tr>
<td>11</td>
<td>CSS8</td>
<td>Float</td>
<td>CSS 8 (CY00) output</td>
<td>0 − 0.0013 amps</td>
</tr>
<tr>
<td>12</td>
<td>coarse_xg</td>
<td>Integer</td>
<td>FSS x-axis coarse data (Gray code)</td>
<td>0 − 64 (equivalent decimal)</td>
</tr>
<tr>
<td>13</td>
<td>coarse_yg</td>
<td>Integer</td>
<td>FSS y-axis coarse data (Gray code)</td>
<td>0 − 64 (equivalent decimal)</td>
</tr>
<tr>
<td>14</td>
<td>sinx</td>
<td>Float</td>
<td>FSS x-axis sin of angle</td>
<td>± 5 volts</td>
</tr>
<tr>
<td>15</td>
<td>cosx</td>
<td>Float</td>
<td>FSS x-axis cos of angle</td>
<td>± 5 volts</td>
</tr>
<tr>
<td>16</td>
<td>siny</td>
<td>Float</td>
<td>FSS y-axis sin of angle</td>
<td>± 5 volts</td>
</tr>
<tr>
<td>17</td>
<td>cosy</td>
<td>Float</td>
<td>FSS y-axis cos of angle</td>
<td>± 5 volts</td>
</tr>
<tr>
<td>18</td>
<td>FSS_SPI</td>
<td>Integer</td>
<td>FSS Sun Presence Indicator</td>
<td>0, 1</td>
</tr>
<tr>
<td>19</td>
<td>xcounts1</td>
<td>Integer</td>
<td>SAS x count 1</td>
<td>± 128</td>
</tr>
<tr>
<td>20</td>
<td>xcounts2</td>
<td>Integer</td>
<td>SAS x count 2</td>
<td>± 128</td>
</tr>
<tr>
<td>21</td>
<td>xcounts3</td>
<td>Integer</td>
<td>SAS x count 3</td>
<td>± 128</td>
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<tr>
<td>22</td>
<td>xcounts4</td>
<td>Integer</td>
<td>SAS x count 4</td>
<td>± 128</td>
</tr>
<tr>
<td>23</td>
<td>xcounts5</td>
<td>Integer</td>
<td>SAS x count 5</td>
<td>± 128</td>
</tr>
<tr>
<td>24</td>
<td>xcounts6</td>
<td>Integer</td>
<td>SAS x count 6</td>
<td>± 128</td>
</tr>
<tr>
<td>25</td>
<td>xcounts7</td>
<td>Integer</td>
<td>SAS x count 7</td>
<td>± 128</td>
</tr>
<tr>
<td>26</td>
<td>xcounts8</td>
<td>Integer</td>
<td>SAS x count 8</td>
<td>± 128</td>
</tr>
<tr>
<td>27</td>
<td>ycounts1</td>
<td>Integer</td>
<td>SAS y count 1</td>
<td>± 128</td>
</tr>
<tr>
<td>28</td>
<td>ycounts2</td>
<td>Integer</td>
<td>SAS y count 2</td>
<td>± 128</td>
</tr>
<tr>
<td>29</td>
<td>ycounts3</td>
<td>Integer</td>
<td>SAS y count 3</td>
<td>± 128</td>
</tr>
<tr>
<td>30</td>
<td>ycounts4</td>
<td>Integer</td>
<td>SAS y count 4</td>
<td>± 128</td>
</tr>
<tr>
<td>31</td>
<td>ycounts5</td>
<td>Integer</td>
<td>SAS y count 5</td>
<td>± 128</td>
</tr>
<tr>
<td>32</td>
<td>ycounts6</td>
<td>Integer</td>
<td>SAS y count 6</td>
<td>± 128</td>
</tr>
<tr>
<td>33</td>
<td>ycounts7</td>
<td>Integer</td>
<td>SAS y count 7</td>
<td>± 128</td>
</tr>
<tr>
<td>34</td>
<td>ycounts8</td>
<td>Integer</td>
<td>SAS y count 8</td>
<td>± 128</td>
</tr>
<tr>
<td>35</td>
<td>SAS_time</td>
<td>Float</td>
<td>SAS time tag</td>
<td>0 − 1e+8 seconds</td>
</tr>
<tr>
<td>36</td>
<td>SC_time</td>
<td>Float</td>
<td>Spacecraft time</td>
<td>0 − 1e+8 seconds</td>
</tr>
<tr>
<td>37</td>
<td>ground_mode</td>
<td>Integer</td>
<td>Ground command mode</td>
<td>1-5</td>
</tr>
<tr>
<td>38</td>
<td>Sun_sensor_toggle</td>
<td>Integer</td>
<td>Sun sensor toggle switch (0=FSS,1=CSS)</td>
<td>0.1</td>
</tr>
</tbody>
</table>
ACS FSW OUTPUT VARIABLES

ACS Telemetry Variables
- 22 Parameters
- 1 flag

<table>
<thead>
<tr>
<th>#</th>
<th>Variable</th>
<th>Type</th>
<th>Description</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>lx</td>
<td>Float</td>
<td>Current to TQRX</td>
<td>± 0.25 amp</td>
</tr>
<tr>
<td>2</td>
<td>ly</td>
<td>Float</td>
<td>Current to TQRY</td>
<td>± 0.25 amp</td>
</tr>
<tr>
<td>3</td>
<td>lz</td>
<td>Float</td>
<td>Current to TQRZ</td>
<td>± 0.25 amp</td>
</tr>
<tr>
<td>4</td>
<td>spin_rate</td>
<td>Float</td>
<td>Spin rate estimate</td>
<td>± 2 rad/sec</td>
</tr>
<tr>
<td>5</td>
<td>mode</td>
<td>Integer</td>
<td>SC operation Mode</td>
<td>1 – 5</td>
</tr>
<tr>
<td>6</td>
<td>MAGx</td>
<td>Float</td>
<td>Magnetic field along x-axis</td>
<td>± 0.0001 tesla</td>
</tr>
<tr>
<td>7</td>
<td>MAGy</td>
<td>Float</td>
<td>Magnetic field along y-axis</td>
<td>± 0.0001 tesla</td>
</tr>
<tr>
<td>8</td>
<td>MAGz</td>
<td>Float</td>
<td>Magnetic field along z-axis</td>
<td>± 0.0001 tesla</td>
</tr>
<tr>
<td>9</td>
<td>CSSx</td>
<td>Float</td>
<td>CSS Sun vector along x-axis</td>
<td>± 1</td>
</tr>
<tr>
<td>10</td>
<td>CSSy</td>
<td>Float</td>
<td>CSS Sun vector along y-axis</td>
<td>± 1</td>
</tr>
<tr>
<td>11</td>
<td>CSSz</td>
<td>Float</td>
<td>CSS Sun vector along z-axis</td>
<td>± 1</td>
</tr>
<tr>
<td>12</td>
<td>FSSx</td>
<td>Float</td>
<td>FSS Sun vector along x-axis</td>
<td>± 1</td>
</tr>
<tr>
<td>13</td>
<td>FSSy</td>
<td>Float</td>
<td>FSS Sun vector along y-axis</td>
<td>± 1</td>
</tr>
<tr>
<td>14</td>
<td>FSSz</td>
<td>Float</td>
<td>FSS Sun vector along z-axis</td>
<td>± 1</td>
</tr>
<tr>
<td>15</td>
<td>CSS_SPI</td>
<td>Integer</td>
<td>CSS Sun Presence Indicator</td>
<td>0, 1</td>
</tr>
<tr>
<td>16</td>
<td>wx</td>
<td>Float</td>
<td>Transverse rate estimate along x-axis</td>
<td>± 0.1 rad/sec</td>
</tr>
<tr>
<td>17</td>
<td>wy</td>
<td>Float</td>
<td>Transverse rate estimate along y-axis</td>
<td>± 0.1 rad/sec</td>
</tr>
<tr>
<td>18</td>
<td>to_idle_flag</td>
<td>Integer</td>
<td>Flag describing transition to Idle Mode</td>
<td>0 – 5</td>
</tr>
<tr>
<td>19</td>
<td>SASx</td>
<td>Float</td>
<td>SAS Sun vector along x-axis</td>
<td>± 1</td>
</tr>
<tr>
<td>20</td>
<td>SASy</td>
<td>Float</td>
<td>SAS Sun vector along y-axis</td>
<td>± 1</td>
</tr>
<tr>
<td>21</td>
<td>SASz</td>
<td>Float</td>
<td>SAS Sun vector along z-axis</td>
<td>± 1</td>
</tr>
<tr>
<td>22</td>
<td>SAS_SPI</td>
<td>Integer</td>
<td>SAS Sun Presence Indicator</td>
<td>0, 1</td>
</tr>
<tr>
<td>23</td>
<td>Css_unusual_flag</td>
<td>Integer</td>
<td>CSS Unusual Setting Indicator</td>
<td>0, 1</td>
</tr>
</tbody>
</table>
\[ B = A^{-1} \frac{1}{F} (V_B - V_{\text{bias}} - C*I) \]

- **A**: Alignment Matrix
- **F**: Scale Factor
- **V_{\text{bias}}**: Signal Bias
- **C**: Torqrod Compensation Matrix

**Note:** 1 Gauss = \(10^{-4}\) Tesla
INPUT PROCESSING - FSS PROCESSING

Determine fractional part

Determine integer part

Determine projection of Sun vector on X & Y axes

SC Body Frame

FSS SPI = 1

[\begin{bmatrix} V_{\text{sinx}} \\ V_{\text{cosx}} \end{bmatrix}, \begin{bmatrix} V_{\text{siny}} \\ V_{\text{cosy}} \end{bmatrix}]^{(V)}

[\begin{bmatrix} V_{\text{x Gray code}} \\ V_{\text{y Gray code}} \end{bmatrix}]

\begin{bmatrix} N_{fx} \\ N_{fy} \end{bmatrix}

\begin{bmatrix} N_{ix} \\ N_{iy} \end{bmatrix}

\begin{bmatrix} X \\ Y \end{bmatrix}

\begin{bmatrix} S_{xFSS} \\ S_{yFSS} \\ S_{zFSS} \end{bmatrix} = \begin{bmatrix} \frac{S_{xFSS}}{\tan(\theta)} \\ \frac{S_{yFSS}}{\tan(\theta)} \\ 1 \end{bmatrix}

\sqrt{1 + \tan^2(\theta) + \tan^2(\theta)}
INPUT PROCESSING - CSS PROCESSING

I (A) → Any cells illuminated

Yes → CSS SPI = 1

No → CSS SPI = 0

> 4 cells illuminated

Yes → CSS unusual settings flag = 1

No → Opposite cells illuminated

Yes → # of cells illuminated

k = 0

No → # of cells illuminated

0 ≤ k ≤ 4

for k = 0 - $S_{CSS} = \text{old } S_{CSS}$

for k = 1:4 - $S_{CSS} = \text{updated } S_{CSS}$

$S_{CSS}$
INPUT PROCESSING - SAS PROCESSING

Determine counts to use

\[
\begin{bmatrix}
\text{xcount} \\
\text{ycount}
\end{bmatrix}
\]

If \( \text{xcount} = -128 \) or \( \text{ycount} = -128 \)

Yes

\[
S_{\text{SAS}} = \text{old } S_{\text{SAS}} \\
S_{\text{SAS}} \text{ SPI} = 0
\]

No

\[
\begin{align*}
\dot{\theta} &= \Delta T_{\text{SAS}} \ast \Omega \\
S_{x_{\text{SAS}}} &= (\text{xcount} \ast \cos(\dot{\theta}) + \text{ycount} \ast \sin(\dot{\theta})) \ast sf \\
S_{y_{\text{SAS}}} &= (\text{ycount} \ast \cos(\dot{\theta}) - \text{xcount} \ast \sin(\dot{\theta})) \ast sf \\
S_{z_{\text{SAS}}} &= \sqrt{1 - S_{x_{\text{SAS}}}^2 - S_{y_{\text{SAS}}}^2} \\
\text{SAS SPI} &= 1
\end{align*}
\]

SP Jain
MODE CONTROL LOGIC - TOP LEVEL

Acquisition Mode

Precession Mode

Normal Mode

Spin Mode

Idle Mode

Mode

If Mode = 1

Acquisition Mode

If Mode = 2

Precession Mode

Magnetic moment

Scale Factor

Torqrod current command

If Mode = 3

Normal Mode

\[
\begin{bmatrix}
M_x \\
M_y \\
M_z
\end{bmatrix}
\]

\[(A \cdot m^2)\]

\[
\begin{bmatrix}
I_x \\
I_y \\
I_z
\end{bmatrix}
\]

\[(A)\]

If Mode = 4

Spin Mode

Transverse rate estimates

\[
\begin{bmatrix}
\dot{u}_x \\
\dot{u}_y \\
\dot{u}_z
\end{bmatrix}
\]

\[(rad/sec)\]

If Mode = 5

Idle Mode
MODE CONTROL LOGIC - ACQUISITION MODE

First-order Filters

Second-order Filters

B-dot Control Law

\[ M = -K_A \begin{bmatrix} \dot{B}_{sf} - \tilde{\dot{B}}_A \dot{B}_{sf} \\ \dot{B}_{yf} + \tilde{\dot{B}}_A \dot{B}_{sf} \\ \dot{B}_{zf} \end{bmatrix} \]

\[ \pm 60 \text{A} \cdot \text{m}^2 \]

\[ \begin{bmatrix} M_x \\ M_y \\ M_z \end{bmatrix} (\text{A} \cdot \text{m}^2) \]
MODE CONTROL LOGIC - PRECESSION MODE

First-order Filters

2nd-order Filters

First-order Filters

Coarse Precession Control

\[
M_x = 0 \\
M_y = 0 \\
M_z = -K_A \dot{B}_s + K_{P, CSS} \text{sign} (B_s S_y - B_y S_x)
\]

\[
\pm 60 \text{A} \cdot \text{m}^2
\]

Fine SPI = 1

Use FSS or SAS

Fine S

First-order Filters

2nd-order Filters

\[
\dot{\Omega} = S_t
\]

Estimate \( \dot{\omega}_x, \dot{\omega}_y \)

\[
\begin{bmatrix}
\dot{\omega}_x \\
\dot{\omega}_y
\end{bmatrix} = K_{P, FSS} \hat{S}_f - K_{N, FSS} \hat{u}_{sf}
\]

\[
\hat{u}_{sf, yf} \\
\hat{u}_{yf}
\]

First-order Filters

\[
\begin{bmatrix}
M_x \\
M_y \\
M_z
\end{bmatrix} = \begin{bmatrix}
0 \\
0 \\
0
\end{bmatrix} + \begin{bmatrix}
B_{sf} \dot{\omega}_y - B_{yf} \dot{\omega}_x \\
\left( B_{sf}^2 + B_{yf}^2 \right)
\end{bmatrix}
\]

\[
\pm 60 \text{A} \cdot \text{m}^2
\]

Fine Precession Control

[46]
Nominal Initial Conditions:
• At Tip-off:
  • Body Rates (4, 4, 17) deg/sec
  • Momentum Vector 5 deg from Sun
• After Solar Array Deployment:
  • Body Rates (2.6, 2.6, 3.2) deg/sec
  • Momentum Vector 7 deg from Sun

Event Sequence:
• Immediately Following CPU Boot-Up ACS Begins Operation
  in Acquisition Mode
• Torque Rods Inactive for Initial 10 minutes to Allow for
  Proper Solar Array Deployment
• After 2.5 Hours, ACS Transitions to Precession Mode
• If Sun Error < 5 deg and Spin Rate > 0.12rpm within 2.5
  hours, ACS will Transitions to Normal Mode then to Idle Mode
  (see Mode Transition Logic)
• Once the Sun is within 5 deg of Z-axis, ACS Transitions to
  Idle Mode.

Note:
• Assume Eclipses Occur during the First 30 Minutes of Each
  97 Min Orbit. Torque Rods are Disabled while in Eclipse
• Spin Rate Estimation is Poor for Low Spin Rates
MODE CONTROL LOGIC - NORMAL MODE

High Energy Solar Spectroscopic Imager (HESSI)

First-order Filters

\[
\begin{align*}
\cos^{-1}\left(\sqrt{1 - S_x^2 - S_y^2}\right) & \Rightarrow \hat{a} \\
\end{align*}
\]

First-order Filters

\[
\begin{align*}
\hat{\omega}_x, \hat{\omega}_y & \Rightarrow \left[\begin{array}{c}
\hat{u}_x \\
\hat{u}_y 
\end{array}\right] \\
\end{align*}
\]

\[
\begin{align*}
\dot{\hat{\omega}}_x = K_{P,FSS} \hat{S}_{xf} - K_{N,FSS} \hat{u}_{xf} \\
\dot{\hat{\omega}}_y = \hat{S}_{yf} \\
\end{align*}
\]

\[
\begin{align*}
\hat{\omega}_x & = M \left( \frac{B_{xf} \hat{\omega}_x - B_{yf} \hat{\omega}_y}{B_{xf}^2 + B_{yf}^2} \right) \\
\hat{\omega}_y & = \hat{\omega}_y \\
\end{align*}
\]

\[
\begin{align*}
M_z & = |\hat{e}| \left( \frac{B_{xf} \hat{\omega}_x - B_{yf} \hat{\omega}_y}{B_{xf}^2 + B_{yf}^2} \right) \\
\end{align*}
\]

\[
\begin{align*}
M_x = \left[ \begin{array}{c}
K_s \Omega_s - \hat{\Omega} \\
- K_s \Omega_s - \hat{\Omega} 
\end{array}\right] \\
M_y = \left[ \begin{array}{c}
0 \\
K_s \Omega_s - \hat{\Omega} 
\end{array}\right] \\
\end{align*}
\]

\[
\begin{align*}
M_x^2 + M_y^2 & = \pm 10A - m^2 \\
\end{align*}
\]

\[
\begin{align*}
M_z^{2} & = \pm 30A - m^2 \\
\end{align*}
\]
Normal Mission Mode Performance:
- Low Torqrod Duty Cycle
  - Min Hysteresis Bound 0.05 deg
  - Max Hysteresis Bounds 0.1 deg
- Sun Error <0.15 deg
- 50% Z-Torque Rod Duty-Cycle During Sun Viewing
HOT BENCH TEST RESULTS FOR NORMAL MODE - HIGH DUTY CYCLE

**Normal Mission Mode Performance:**

- High Torqrod Duty Cycle
  - Min Hysteresis Bound 0.0 deg
  - Max Hysteresis Bounds 0.1 deg
- Sun Pointing Error is Reduced by Half
- 100% Z-Torque Rod Duty-Cycle During Sun Viewing

![HESSI ACS Hot Bench Test: FSW Telemetry Data Plot](image-url)
MODE CONTROL LOGIC - SPIN MODE

\[
\begin{bmatrix}
M_x \\
M_y
\end{bmatrix} = 
\begin{bmatrix}
K_S \frac{\Omega_s - \Omega}{(B_{sf}^2 + B_{yf}^2)} B_{yf} \\
- K_S \frac{\Omega_s - \Omega}{(B_{sf}^2 + B_{yf}^2)} B_{sf}
\end{bmatrix}
\]

\[\mathbf{M}_z = \text{Fine Precession Control as in Precession Mode}\]

\[\pm 60 \text{A} \cdot \text{m}^2\]
**Spin Up Performance:**
- SC Spins Up from 0.25 rpm to 14.5 rpm in 50 Hours
- Sun Error is Controlled During Spin-Up

**Comments:**
- Several Smaller Steps of Spin-Up may Be Desirable During On-Orbit Operation to Reduce the Peak Sun Error
MODE CONTROL LOGIC - IDLE MODE

\[
\begin{bmatrix}
M_x \\
M_y \\
M_z
\end{bmatrix} =
\begin{bmatrix}
0 \\
0 \\
0
\end{bmatrix}
\]
ACS COMMANDS

ACS FSW Related Commands:

**ACSETMODE AUTO** - Allows Autonomous Mode Selection
**ACQUISITION** - To Damp Out Transverse Rates and Establish Desired Low Spin Rate
**PRECESSION** - To Establish Sun Pointing Orientation
**NORMAL** - To Maintain Nominal Spin Rate and Sun Pointing
**SPIN** - To Establish Desired Spin Rate
**IDLE** - To Disable Control Until Ground Intervention

**ACSSUNSENSOR FSS** - Select FSS as the Fine Sun Sensor for ACS Controls
**SAS** - Select SAS as the Fine Sun Sensor for ACS Controls

**Strongly Recommended**: Consult Spectrum ACS Engineers Prior to Selecting SAS for ACS Control.
## ACS COMMAND PARAMETERS 1-30

### Present Default ACS Parameter Table
- 153 Parameters

Note: The Default Values of Some Parameters may Need to be Changed.

<table>
<thead>
<tr>
<th>#</th>
<th>Parameter</th>
<th>Type</th>
<th>Default Value</th>
<th>Description</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>mode_command</td>
<td>Integer</td>
<td>1</td>
<td>Initial Mode setting</td>
<td>1-5</td>
</tr>
<tr>
<td>2</td>
<td>css_thresh</td>
<td>Float</td>
<td>0.0005 amp</td>
<td>CSS threshold</td>
<td>0 – 0.001</td>
</tr>
<tr>
<td>3</td>
<td>fss_bias_x</td>
<td>Float</td>
<td>0</td>
<td>FSS bias along x-axis</td>
<td>± 1</td>
</tr>
<tr>
<td>4</td>
<td>fss_bias_y</td>
<td>Float</td>
<td>0</td>
<td>FSS bias along y-axis</td>
<td>± 1</td>
</tr>
<tr>
<td>5</td>
<td>mag_bias_x</td>
<td>Float</td>
<td>0 tesla</td>
<td>MAG bias along x-axis</td>
<td>± 0.0001</td>
</tr>
<tr>
<td>6</td>
<td>mag_bias_y</td>
<td>Float</td>
<td>0 tesla</td>
<td>MAG bias along y-axis</td>
<td>± 0.0001</td>
</tr>
<tr>
<td>7</td>
<td>sas_delay</td>
<td>Float</td>
<td>2.5 sec</td>
<td>SAS data delay</td>
<td>0 – 5.0</td>
</tr>
<tr>
<td>8</td>
<td>tqr_comp11</td>
<td>Float</td>
<td>0.671259 volts/amp</td>
<td>Torqrod compensation matrix component</td>
<td>± 20</td>
</tr>
<tr>
<td>9</td>
<td>tqr_comp12</td>
<td>Float</td>
<td>-0.06135 volts/amp</td>
<td>Torqrod compensation matrix component</td>
<td>± 20</td>
</tr>
<tr>
<td>10</td>
<td>tqr_comp13</td>
<td>Float</td>
<td>0.881908 volts/amp</td>
<td>Torqrod compensation matrix component</td>
<td>± 20</td>
</tr>
<tr>
<td>11</td>
<td>tqr_comp21</td>
<td>Float</td>
<td>0.161945 volts/amp</td>
<td>Torqrod compensation matrix component</td>
<td>± 20</td>
</tr>
<tr>
<td>12</td>
<td>tqr_comp22</td>
<td>Float</td>
<td>1.026166 volts/amp</td>
<td>Torqrod compensation matrix component</td>
<td>± 20</td>
</tr>
<tr>
<td>13</td>
<td>tqr_comp23</td>
<td>Float</td>
<td>-0.36266 volts/amp</td>
<td>Torqrod compensation matrix component</td>
<td>± 20</td>
</tr>
<tr>
<td>14</td>
<td>tqr_comp31</td>
<td>Float</td>
<td>0.424606 volts/amp</td>
<td>Torqrod compensation matrix component</td>
<td>± 20</td>
</tr>
<tr>
<td>15</td>
<td>tqr_comp32</td>
<td>Float</td>
<td>-0.41646 volts/amp</td>
<td>Torqrod compensation matrix component</td>
<td>± 20</td>
</tr>
<tr>
<td>16</td>
<td>tqr_comp33</td>
<td>Float</td>
<td>-0.69728 volts/amp</td>
<td>Torqrod compensation matrix component</td>
<td>± 20</td>
</tr>
<tr>
<td>17</td>
<td>tqr_sat_high</td>
<td>Float</td>
<td>60 amp-m²</td>
<td>Torqrod high saturation level</td>
<td>0 – 100</td>
</tr>
<tr>
<td>18</td>
<td>tqr_sat_point_low</td>
<td>Float</td>
<td>30 amp-m²</td>
<td>Torqrod low saturation level in pointing</td>
<td>0 – 100</td>
</tr>
<tr>
<td>19</td>
<td>tqr_sat_spin_low</td>
<td>Float</td>
<td>10 amp-m²</td>
<td>Torqrod low saturation level in spin</td>
<td>0 – 100</td>
</tr>
<tr>
<td>20</td>
<td>acq_spin_com</td>
<td>Float</td>
<td>0.035 rad/sec</td>
<td>Commanded spin rate during Acquisition</td>
<td>0 – 0.1</td>
</tr>
<tr>
<td>21</td>
<td>norm_spin_com</td>
<td>Float</td>
<td>1.57 rad/sec</td>
<td>Commanded spin rate during Normal operation</td>
<td>0 – 2</td>
</tr>
<tr>
<td>22</td>
<td>acq_gain</td>
<td>Double</td>
<td>1e+11 amp-m³-sec/tesla</td>
<td>Acquisition control gain</td>
<td>0 – 1e+11</td>
</tr>
<tr>
<td>23</td>
<td>coarse_prec_gain</td>
<td>Float</td>
<td>1e+4 amp-m²</td>
<td>Coarse Precession control gain</td>
<td>0 – 1e+6</td>
</tr>
<tr>
<td>24</td>
<td>fine_prec_gain</td>
<td>Float</td>
<td>1.5 N-m-sec</td>
<td>Fine Precession control gain</td>
<td>0 – 5</td>
</tr>
<tr>
<td>25</td>
<td>fine_nut_gain</td>
<td>Float</td>
<td>4.5 N-m-sec</td>
<td>Fine nutation control gain</td>
<td>0 – 20</td>
</tr>
<tr>
<td>26</td>
<td>spin_gain</td>
<td>Float</td>
<td>1 amp-m²-sec/tesla</td>
<td>Spin control gain</td>
<td>0 – 10</td>
</tr>
<tr>
<td>27</td>
<td>point_high</td>
<td>Float</td>
<td>0.001745 rad</td>
<td>High setting for pointing hysteresis logic</td>
<td>0 – 0.004</td>
</tr>
<tr>
<td>28</td>
<td>point_low</td>
<td>Float</td>
<td>0.0008725 rad</td>
<td>Low setting for pointing hysteresis logic</td>
<td>0 – 0.002</td>
</tr>
<tr>
<td>29</td>
<td>point_check*</td>
<td>Integer</td>
<td>1</td>
<td>Initial state of pointing hysteresis logic</td>
<td>0, 1</td>
</tr>
<tr>
<td>30</td>
<td>delta_spin_high</td>
<td>Float</td>
<td>0.1 rad/sec</td>
<td>High setting for spin hysteresis logic</td>
<td>0 – 0.4</td>
</tr>
</tbody>
</table>
## ACS COMMAND PARAMETERS 31-60

### High Energy Solar Spectroscopic Imager (HESSI)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Type</th>
<th>Value</th>
<th>Description</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>31</td>
<td>delta_spin_low</td>
<td>Float</td>
<td>0.05 rad/sec</td>
<td>Low setting for spin hysteresis logic</td>
</tr>
<tr>
<td>32</td>
<td>spin_check*</td>
<td>Integer</td>
<td>1</td>
<td>Initial state of spin hysteresis logic</td>
</tr>
<tr>
<td>33</td>
<td>point_acq2norm</td>
<td>Float</td>
<td>0.0873 rad</td>
<td>Transition pointing error from Acquisition to Normal</td>
</tr>
<tr>
<td>34</td>
<td>point_prec2norm</td>
<td>Float</td>
<td>0.0035 rad</td>
<td>Transition pointing error from Precession to Normal</td>
</tr>
<tr>
<td>35</td>
<td>point_norm2idle</td>
<td>Float</td>
<td>0.0088 rad</td>
<td>Transition pointing error from Normal to Idle</td>
</tr>
<tr>
<td>36</td>
<td>point_spin2norm</td>
<td>Float</td>
<td>0.0035 rad</td>
<td>Transition pointing error from Spin to Normal</td>
</tr>
<tr>
<td>37</td>
<td>rate_acq2norm</td>
<td>Float</td>
<td>0.0126 rad/sec</td>
<td>Transition rate from Acquisition to Normal</td>
</tr>
<tr>
<td>38</td>
<td>dbrate_prec2norm</td>
<td>Float</td>
<td>0.05 rad/sec</td>
<td>Transition rate error from Precession to Normal</td>
</tr>
<tr>
<td>39</td>
<td>dbrate_norm2idle</td>
<td>Float</td>
<td>0.15 rad/sec</td>
<td>Transition rate error from Normal to Idle</td>
</tr>
<tr>
<td>40</td>
<td>dbrate_spin2norm</td>
<td>Float</td>
<td>0.05 rad/sec</td>
<td>Transition rate error from Spin to Normal</td>
</tr>
<tr>
<td>41</td>
<td>time_acq2norm</td>
<td>Float</td>
<td>600 sec</td>
<td>Transition time from Acquisition to Normal</td>
</tr>
<tr>
<td>42</td>
<td>time_acq2prec</td>
<td>Float</td>
<td>9000 sec</td>
<td>Transition time from Acquisition to Precession</td>
</tr>
<tr>
<td>43</td>
<td>time_prec2norm</td>
<td>Float</td>
<td>60</td>
<td>Transition time from Precession to Normal</td>
</tr>
<tr>
<td>44</td>
<td>time_prec2idle</td>
<td>Float</td>
<td>600 sec</td>
<td>Transition time from Precession to Idle</td>
</tr>
<tr>
<td>45</td>
<td>time_norm2idle_ang</td>
<td>Float</td>
<td>2 sec</td>
<td>Transition time from Normal to Idle due to pointing error</td>
</tr>
<tr>
<td>46</td>
<td>time_norm2idle_rate</td>
<td>Float</td>
<td>2 sec</td>
<td>Transition time from Normal to Idle due to rate error</td>
</tr>
<tr>
<td>47</td>
<td>time_prec2idle</td>
<td>Float</td>
<td>2 sec</td>
<td>Transition time from Precession to Idle</td>
</tr>
<tr>
<td>48</td>
<td>time_spin2idle</td>
<td>Float</td>
<td>2 sec</td>
<td>Transition time from Spin to Idle</td>
</tr>
<tr>
<td>49</td>
<td>time_init2tqr</td>
<td>Float</td>
<td>600 sec</td>
<td>Initial Torqrod waiting time</td>
</tr>
<tr>
<td>50</td>
<td>point_err_chk</td>
<td>Float</td>
<td>4 cycles</td>
<td>Persistent pointing error check time in Normal mode</td>
</tr>
<tr>
<td>51</td>
<td>time_bootwait</td>
<td>Float</td>
<td>120 sec</td>
<td>Initial mode transition wait time</td>
</tr>
<tr>
<td>52</td>
<td>sa_x1_ang</td>
<td>Float</td>
<td>5 deg</td>
<td>+X solar panel rotation angle</td>
</tr>
<tr>
<td>53</td>
<td>sa_y1_ang</td>
<td>Float</td>
<td>5 deg</td>
<td>+Y solar panel rotation angle</td>
</tr>
<tr>
<td>54</td>
<td>sa_x0_ang</td>
<td>Float</td>
<td>5 deg</td>
<td>-X solar panel rotation angle</td>
</tr>
<tr>
<td>55</td>
<td>sa_y0_ang</td>
<td>Float</td>
<td>5 deg</td>
<td>-Y solar panel rotation angle</td>
</tr>
<tr>
<td>56</td>
<td>sa_normal_ang</td>
<td>Float</td>
<td>35 deg</td>
<td>Angle between CSS normal vector and solar panel</td>
</tr>
<tr>
<td>57</td>
<td>css_sf_amp</td>
<td>Float</td>
<td>0.0013 amp</td>
<td>CSS scale factor</td>
</tr>
<tr>
<td>58</td>
<td>switch_css_fss</td>
<td>Integer</td>
<td>0</td>
<td>Switch between CSS and FSS</td>
</tr>
<tr>
<td>59</td>
<td>west_dct_limit</td>
<td>Float</td>
<td>1.5 sec</td>
<td>B field multiple zero crossing check time</td>
</tr>
<tr>
<td>60</td>
<td>west_dw_limit</td>
<td>Float</td>
<td>2 rad/sec</td>
<td>Spin rate estimation upper limit</td>
</tr>
<tr>
<td>Parameter</td>
<td>Type</td>
<td>Value</td>
<td>Description</td>
<td>Range</td>
</tr>
<tr>
<td>-------------</td>
<td>-------</td>
<td>---------------------------------</td>
<td>--------------------------------------------------</td>
<td>---------------</td>
</tr>
<tr>
<td>61</td>
<td>tar sf m21</td>
<td>Float -0.00382 1/m²</td>
<td>Torque rod scale factor</td>
<td>-0.007 - 0</td>
</tr>
<tr>
<td>62</td>
<td>mag sig biaxx</td>
<td>Float -0.0210 volts</td>
<td>MAG signal X-axis bias</td>
<td>± 0.2</td>
</tr>
<tr>
<td>63</td>
<td>mag sig biasy</td>
<td>Float -0.0222 volts</td>
<td>MAG signal Y-axis bias</td>
<td>± 0.2</td>
</tr>
<tr>
<td>64</td>
<td>mag sig biasz</td>
<td>Float -0.0078 volts</td>
<td>MAG signal Z-axis bias</td>
<td>± 0.2</td>
</tr>
<tr>
<td>65</td>
<td>mag sig invsf x</td>
<td>Float 1.228894e-5 tesla/volts</td>
<td>MAG signal X-axis scale factor inverse</td>
<td>0 – 1e-4</td>
</tr>
<tr>
<td>66</td>
<td>mag sig invsf y</td>
<td>Float 1.198365e-5 tesla/volts</td>
<td>MAG signal Y-axis scale factor inverse</td>
<td>0 – 1e-4</td>
</tr>
<tr>
<td>67</td>
<td>mag sig invsf z</td>
<td>Float 1.206855e-5 tesla/volts</td>
<td>MAG signal Z-axis scale factor inverse</td>
<td>0 – 1e-4</td>
</tr>
<tr>
<td>68</td>
<td>mag sig mis11</td>
<td>Float 1.00038</td>
<td>Inverse MAG misalignment matrix component</td>
<td>0 – 2</td>
</tr>
<tr>
<td>69</td>
<td>mag sig mis12</td>
<td>Float 0.01063</td>
<td>Inverse MAG misalignment matrix component</td>
<td>± 0.2</td>
</tr>
<tr>
<td>70</td>
<td>mag sig mis13</td>
<td>Float -0.02069</td>
<td>Inverse MAG misalignment matrix component</td>
<td>± 0.2</td>
</tr>
<tr>
<td>71</td>
<td>mag sig mis21</td>
<td>Float 0.01609</td>
<td>Inverse MAG misalignment matrix component</td>
<td>± 0.2</td>
</tr>
<tr>
<td>72</td>
<td>mag sig mis22</td>
<td>Float 1.00029</td>
<td>Inverse MAG misalignment matrix component</td>
<td>0 – 2</td>
</tr>
<tr>
<td>73</td>
<td>mag sig mis23</td>
<td>Float -0.00372</td>
<td>Inverse MAG misalignment matrix component</td>
<td>± 0.2</td>
</tr>
<tr>
<td>74</td>
<td>mag sig mis31</td>
<td>Float -0.00820</td>
<td>Inverse MAG misalignment matrix component</td>
<td>± 0.2</td>
</tr>
<tr>
<td>75</td>
<td>mag sig mis32</td>
<td>Float 0.01281</td>
<td>Inverse MAG misalignment matrix component</td>
<td>± 0.2</td>
</tr>
<tr>
<td>76</td>
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<tr>
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<td>FSS misalignment matrix component</td>
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<td>Float 0.9681</td>
<td>MAGX filter pole</td>
<td>0 – 0.9999</td>
</tr>
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<td>MAGX filter gain</td>
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<td>Range</td>
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<td>± 5</td>
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<td>± 5</td>
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<td>FSSy 2nd order derivative gain k</td>
<td>± 50</td>
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<td>0 – 0.9999</td>
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<tr>
<td>138 css_filter_gainx</td>
<td>Float</td>
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<td>CSSx filter gain</td>
<td>0 – 2</td>
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<tr>
<td>139 css_filter_zeroy</td>
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<td>CSSy filter zero</td>
<td>0 – 0.9999</td>
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<td>CSSy filter pole</td>
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<td>Spin rate estimation filter gain</td>
<td>0 – 2</td>
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</tbody>
</table>
ACS OPERATIONS

Normal Operations

Screens

Safe Mode

Anomalies and Contingencies

Under voltage
During Normal Mission Operation:

• Mode: Normal
• FSS Sun Pointing Error < 0.2 deg
• Spin Rate Estimation: 15 ± 0.5 rpm
• Magnetic Field Vector Updating Constantly
• Z-Torque Rod Firing for Precession
• X, Y-axis Torque Rod Firing for Spin Rate Regulation

During Initial Acquisition Phase:

• Initial Mode After Separation Should Be Acquisition
• After 2.5 Hours, the SC Should Transition to Precession Mode
• When CSS Sees the Sun (SPI is High), CSS Error Should be Decreasing
• FSS Error Should be Updating whenever FSS Sees the Sun and CSS/FSS Error <= 32 deg
• Magnetometer Measurement Should be Updating Constantly
• X, Y and Z Torque Rods Should be Activated in Acquisition Mode All the Times
• Z Torque Rod Should Be Activated in Precession Mode When SC is In the Sun
## Analog Inputs:
- FSS Analog: (-5 ~ 5 Volts)
- MAG: (-5 ~ 5) Volts
- MAG Temperature: (-40 ~ 90°C) (0 ~ 5V)
- FSS SOH: (0 ~ 5 Volts)
- 4 Torqrod Currents: (-0.2292 ~ 0.2292 A)

## Temperature Sensors AD590s: (deg C)
- FSE
- 2 IAD
- 4 Torque rods
- 4 S/A Wings

## IAD Positions:
- (-10 ~ 3 Volts)

## CSS Current Inputs:
- 8 Channel (0 ~ 1300 µA)

## Digital Inputs:
- FSS Sun Presence: (0,1)
- FSS Coarse Gray-Code Bits: (0000 ~ 1111)
- FSS Coarse Bit Decimal Values: (0 ~ 63)
- FSS Coarse Bit Hex Values: (0000 ~ FFFF)
ACS Information:
- Mode Command Status: Commanded or Auto
- Current ACS Mode:
- Idle Mode Transition Indicator (0 ~ 5)
- ACS Primary Control Sun Sensor in Use
- Actual and Commanded Torque Rod Currents (Amp)
- Magnetic Field (Gauss)
- FSS, CSS, SAS
  - Sun Vector
  - Pointing Error Calculation (deg)
  - Sun Presence Indicator
- Transverse Rate Estimations (rad/sec)
- Spin Rate Estimation (rpm)

Others:
- Telemetry Command Status
- Sun Pointing Error Fault Monitor (0, 1):
  - Disabled by Default
  - Must be Enabled from Ground
  - When Set to 1:
    - Torqrods Powered Down
    - No Commands Sent to ACS
- IAD Selection
- IAD Rotation Direction
Displays Detailed Fine Sun Sensor Information:

- Current ACS Mode
- Mode Command Status: Commanded or Auto
- ACS Primary Control Sun Sensor in Use
- FSS Sun Presence: 1=SUN, 0=NO_SUN
- FSS Sun Vector
- FSS Pointing Error Calculation (deg)
- For X and Y Axes:
  - sine/cosine Signal (Volts)
  - Coarse Bits
  - Pointing Error Estimation (deg)
- FSS Electronics Outputs
  - Power Status
  - FSE Temperature
  - State of Health (SOH)
    - 3.5 V Nominal
Displays Detailed Coarse Sun Sensor Information:

- Current ACS Mode
- Mode Command Status: Commanded or Auto
- ACS Primary Control Sun Sensor in Use
- CSS Sun Presence
- CSS Sun Vector
- CSS Pointing Error Calculation
- 8 CSS Channel Current Outputs:
  - (0 ~1300µA)

Solar Array Release Status:

- X-axis Lower Pri/Sec Release
- X-axis Upper Pri/Sec Release
- Y-axis Lower Pri/Sec Release
- Y-axis Upper Pri/Sec Release
To be Added
Idle Mode is Considered a Safe Mode for HESSI:
• All Torque Rods Are Disabled
• Sun Pointing Error shall Accumulate Approximately 1 deg/Day During Idle Mode

A Flag Indicates the Possible Causes for Autonomous Transition to Idle Mode:

\[
to\_idle\_flag = \begin{cases} 
0 & \text{- No Transition to Idle Mode} \\
1 & \text{- Not used} \\
2 & \text{- Precession to Idle: } \beta < 5 \text{ deg AND NOT } 14.5 < \Omega < 15.5 \text{rpm} \\
3 & \text{- Normal to Idle: } \beta > 0.5 \text{ deg} \\
4 & \text{- Normal to Idle: NOT } 13.5 < \Omega < 16.5 \text{rpm} \\
5 & \text{- Spin to Idle: } 14.5 < \Omega < 15.5 \text{rpm AND NOT } \beta < 0.2 \text{ deg} 
\end{cases}
\]

Autonomous Transitions 3 and 4 Indicate Possible Anomalies During Normal Mode:
• Pointing Error is out of Acceptable Range, or
• Spin Rate Falls Out of the Operating Range
**ANOMALY 1 - STOWED SOLAR ARRAYS**

**+X Solar Array Not Deployed:**
- Shown for 10 Orbits of Simulation for Initial Acquisition Phase with a Nominal LV Tip-off Conditions
- Other 3 Solar Arrays will be Able to Generate Sufficient Power - Maximum DOD=23%

**Contingence:**
- Deploy Stowed Solar Array from Ground

![Graph showing Initial Acquisition with +X Solar Arrays Stowed](image-url)
One or Two CSS Cells Fail During Initial Acquisition Phase:

- Assume No Current Output from Failed Cells
- Assume Nominal Tip-Off Rates (4, 4, 17) deg/sec
- Assume Tip-Off Orientation: 90 deg from the Sun
- SC Should be able to Acquire the Sun for up to Two Cell Failure Cases
- May Need to Modify ACS FSW to Discontinue the Use of Bad CSS Channels
ANOMALY 3 - FSS FAILURE

**FSS Fails During Initial Acquisition Phase:**
- CSS should be able to Save the Spacecraft by Pointing Z-axis toward the Sun
- CSS is Designed for Pointing SC to Sun Coarsely, therefore, Precession Performance using CSS is Not as Good as Using FSS
- SC will Stay in Precession Mode without Ground Interference

**Contingence:**
- Switch CSS in Place of FSS (in Future Version of ACS FSW)

**FSS Fails During Normal Mission Operation:**
- CSS can't Meet Mission Pointing Requirement of 0.2 deg Because of its Low Accuracy (1~2 deg)

**Contingence:**
- Using CSS + SAS for Possible Limited Mission Capability (May be in Future Version of ACS FSW)
MAG Failure

• No Magnetic Field Measurement from MAG

Contingence:

• None
**Under-voltage trip levels**

- UV1 Level is 26.85V Nominal and 24.86V Degraded Mode
- UV2 Level is 26.33V Nominal and 24.15V Degraded Mode
- UV3 Level is 25.70V Nominal and 23.54V Degraded Mode

**Under-voltage trip action**

- UV1 Causes IDPU Safe Mode Signal to Be Sent
- UV2 Turns off Torque Rods, FSS, Magnetometer and CPU
- UV3 Turns off All Switches. Transmitter and Receiver Will Still Work. Ground Command to Turn On CPU